

What Will Fuel the Energy Transition: A Comparison of Hydrogen and Ammonia — Is There a Clear Winner?

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Investments and tax incentives provided by the Inflation Reduction Act of 2022 (IRA) and the US government's ambitious climate goal of reaching net zero emissions by 2050 have fueled a push for alternative clean energy sources.

The energy sector is now grappling with how to reach net zero emissions most efficiently. Liquid hydrogen (H₂) and ammonia (NH₃) are two fuel sources that present promising carbon-neutral energy storage and transportation options. Hydrogen seems like the ideal energy storage and transportation vector due to its high energy potential by weight, but, as explained further below, it is difficult and costly to store, making ammonia an enticing alternative. Which source will ultimately get the United States to its net zero goal — and emerge as a global clean energy storage commodity — depends on a variety of factors, including, potential uses as fuel, the availability of transportation infrastructure, safety considerations, and market conditions.

Uses as Fuel: Both ammonia and hydrogen appear to be the go-to replacements for hydrocarbons as fuel sources. Hydrogen has shown promise as a fuel in aerospace, and as fuel cell technologies grow, hydrogen-fueled cars may someday surpass electric cars. Hydrogen also shows promise in power generation. Wind and solar are important sources for renewable electrical energy, but when the wind doesn't blow or the sun doesn't shine, natural gas turbines need to be available, and natural gas turbines have been operated effectively (and with lower emissions) with a blend of natural gas and hydrogen and most recently with 100% hydrogen. Ammonia shows promise as a replacement fuel for the maritime industry, as tests have shown that

ocean-going vessels can be retrofitted to operate using ammonia as a fuel, significantly lowering the carbon footprint. As decarbonization remains a goal of the global supply chain industry, decarbonization is an even greater priority for the global cruise ship industry. As large-scale hydrogen production projects look to distribute their product in a global market, hydrogen producers are considering liquid ammonia as “just another delivery system” for hydrogen.

Transportation Infrastructure: The transportation of ammonia and hydrogen involves different infrastructure, safety considerations, and storage methods due to their varying physical properties and intended uses. Both hydrogen and ammonia are transported in either a liquid state or as a compressed gas; however, what’s required to transport each in a safe and efficient manner varies. Ammonia is stored and handled under moderate pressure and temperature conditions. It is transported and stored in tanks or cylinders, making it relatively simple to handle compared with liquid hydrogen. Hydrogen is stored and handled at extremely low temperatures and requires specialized cryogenic storage tanks and equipment. Due to its low boiling point, it has higher energy density but poses challenges related to boil-off and leakage.

Because of ammonia’s use as a key ingredient in fertilizer, the infrastructure for ammonia transport globally is well established, with already-constructed terminals, pipelines, railcars, and tankers designed for pressurized or refrigerated ammonia. Hydrogen infrastructure is less widespread and often requires specialized storage and transport vessels due to the higher pressures and cryogenic conditions involved. Most likely, transporters will have to repurpose liquefied natural gas terminals to receive and process liquid hydrogen.

Safety Considerations: Transportation of both poses unique safety issues that require specialized equipment and precautions. While exposure to high concentrations of ammonia can be harmful, it does not readily react with most materials, making it more straightforward to transport in standard equipment. Though exposure to hydrogen is likely not harmful to the environment or persons, hydrogen is flammable in certain conditions can cause hydrogen embrittlement in certain metals, and has a high diffusion rate, necessitating specialized container and sealing methods to prevent leaks.

Market Conditions: The market conditions for liquid ammonia and liquid hydrogen differ significantly due to their distinct properties, production processes, and applications. Liquid ammonia has a well-established market with stable demand due to its use in the agriculture industry (primarily due to the nitrates in liquid ammonia being used as fertilizers). The current market for liquid hydrogen (industrial uses) is much smaller and less well established; however, the future demand for hydrogen in the emerging clean energy sectors, while near-certain and extensive, is still evolving. The

technical challenges for producing and distributing ammonia and hydrogen as fuels on a global scale are daunting, and the market challenges are equally formidable. Ultimately, how will the markets react to the “if you build it, uses will be found” approach? Markets like certainty and today, the if, how, and when ammonia will power ships around the globe, and the if, how, and when hydrogen will replace hydrocarbons, are anything but certain. The federal incentives of the IRA are driving production forward at an accelerated pace, with a “ready, fire, aim” approach being taken by producers; not surprisingly, markets are reacting. The future global supply of liquid ammonia is now looking to exceed current global demand for nitrates and other agricultural uses, and with the resulting uncertainty of future demand for ammonia, the market’s reaction has been evidenced by a 50% drop in global spot ammonia prices from 2022 to 2023. These initial market reactions have made capital investment in ammonia projects difficult to secure, but as demand grows, market conditions are expected to improve.

Summary: The choice between ammonia and hydrogen depends on specific application requirements, technological advances, safety regulations, and available infrastructure, but we are basically looking at two supplies reaching the market, looking for a demand. Ultimately, it is not going to be an either/or play to get the nation to net zero emissions by 2050, but rather, both hydrogen and ammonia will each have their roles at different stages of the energy transition movement. Importantly, to overcome the transportation issues associated with hydrogen, ammonia is a possible solution. As demand for hydrogen within the energy industry grows, storage of hydrogen in the form of ammonia could mitigate many of the practical challenges to hydrogen as a renewable fuel. Alternatively, it could be that ammonia dominates the industry in the near term (market conditions permitting) while hydrogen storage technology advances, after which the price of hydrogen will drop, and ammonia will be replaced. Exactly what alternatives are going to fuel the energy transition (pun intended) at this moment is still anybody’s guess, but hydrogen and ammonia will undoubtedly be key players, and as supply and demand find their way to equilibrium, market conditions will also dictate winners and losers.

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